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PUMP TO SOLAR HEATING PANELS

ABSTRACT *In the paper, low power pump serving to pump the lotion in solar heating panels has been presented. The brushless DC motor having induction motor's elements has been used in the construction of this pump. There are no typical sensors of position of the rotor against the stator in this motor. The position of the rotor is determined on the basis of the voltage waveform in artificial zero point. The pump is supplied by 12 V source, thus it can be used in the case of power net breakdown. The paper presents construction of the motor and electronic circuit along with its basic characteristics and the comparison with presently existing pumps.*

Keywords: *Solar heating panels, electrical pumps*

1. INTRODUCTION

A high rise price in electric energy caused potential customers to be interested in the application of solar heating panels into central heating system. In the modern solutions two heat exchangers are used. Glycol (unfreezing

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PROCEEDINGS OF ELECTROTECHNICAL INSTITUTE, Issue 240, 2009

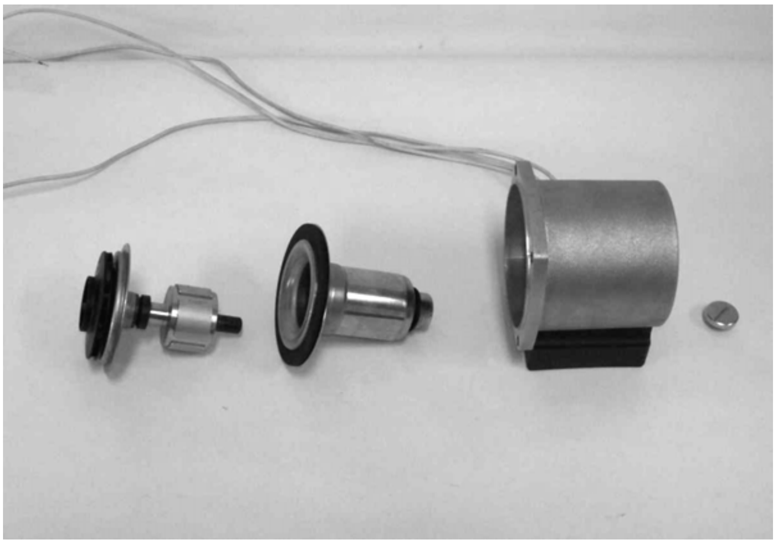
lotion) is used in one of the heat exchanger, thanks to it, the system can also operate in winter. Applications using glycol requires continuous voltage supplying, it is particularly important in summer, when at the lack of lotion circulation and high sun intensity, the breakdown of heating panels can often occur. In this paper, the pump supplying from the source of 12 Volts using in case of the breakdown of power net has been presented. Application of DC brushless motor into the pump allows for the decrease of power consumption in the comparison with present solutions. Additional advantages are the speed control and the change of the efficiency of the pump.

2. CONSTRUCTION OF THE PUMP'S MOTOR

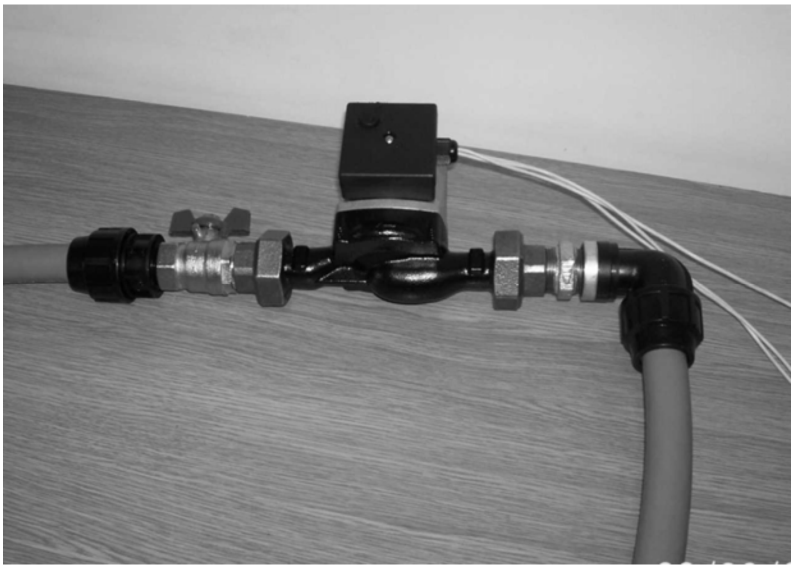
While designing the motor, turning velocity of 2800 rev/min, power of motor of 50 W and supplying voltage equal to 12 Volts were assumed. In the construction of the pump, many already existing elements such as case, bearings, and cylinder separating the wet rotor from motor's windings were used. Steel sheets having 12 grooves have been chosen from the catalog. The neodyme magnet 33SH of parameters of B_r = 1,15 T and H_c = 944 kA/m has also been chosen. In order to calculate the thickness of the magnet protecting the magnetic circuit against the saturation the calculation of the induction in whole magnetic circuit [1], [2], [3], [7] has been performed. Winding parameters were calculated on the basis of induction in the air gap of the motor, turning velocity, the power and supplying voltage of the motor.

On the basis of calculations, the prototype of the pump presenting in Pict. 1, 2 and 3 has been made. These pictures present pump's elements and the view of the prototype in the laboratory.

Pict. 1. The rotor with glued magnets



Pict. 2. Pump's elements: the rotor, the cylinder, case, masking screw



Pict. 3. The prototype of the pump in the laboratory

3. PUMP'S SUPPLYING CIRCUIT

The information about the position of the rotor towards the stator obtaining in classic solution from Hall or optic sensors is needed to proper operation of the motor [4], [5], [6]. At the low limit of turning velocity, it is possible to use sensorless circuit reducing the cost and increasing the reliability of the system. In this solution the position of the rotor is determined on the basis of the measurement of back EMF in zero point of motor's winding at its unavailability in virtual neutral point [8], [9].

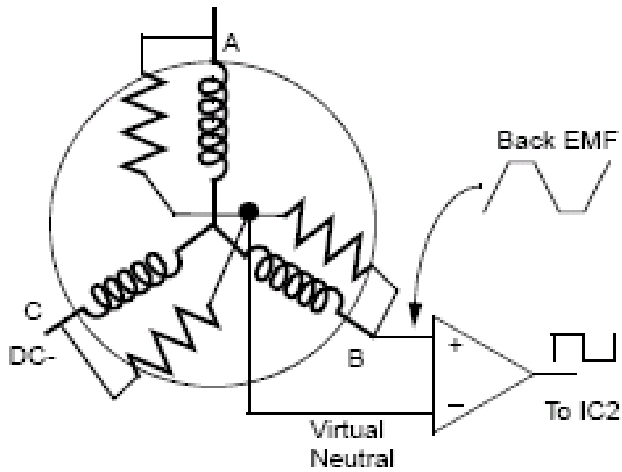


Fig. 1. The measurement of Back EMF in virtual neutral point

Figure 2 presents theoretical voltage waveforms of back EMF in windings and the voltage in the star point of motor's winding.

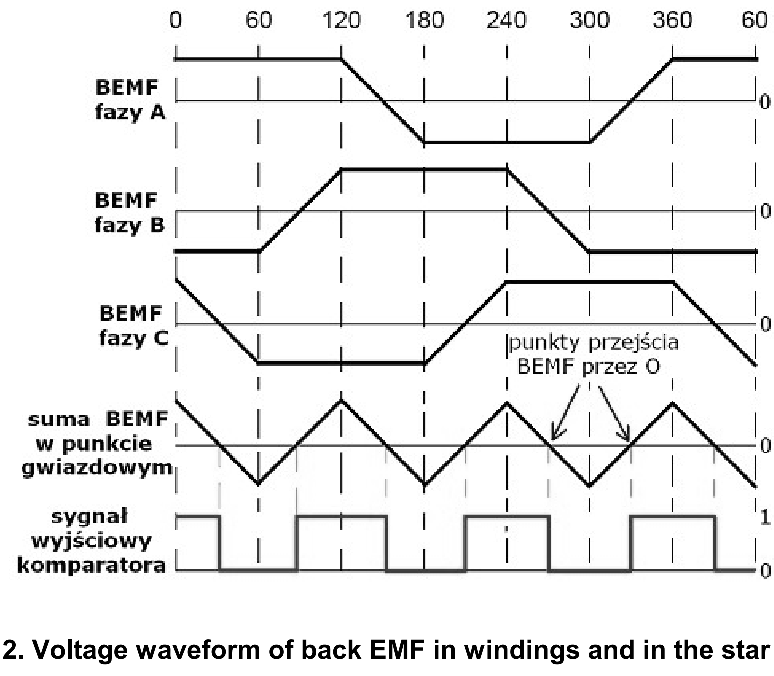


Fig. 2. Voltage waveform of back EMF in windings and in the star point

Actual waveforms are shown in Fig. 3.

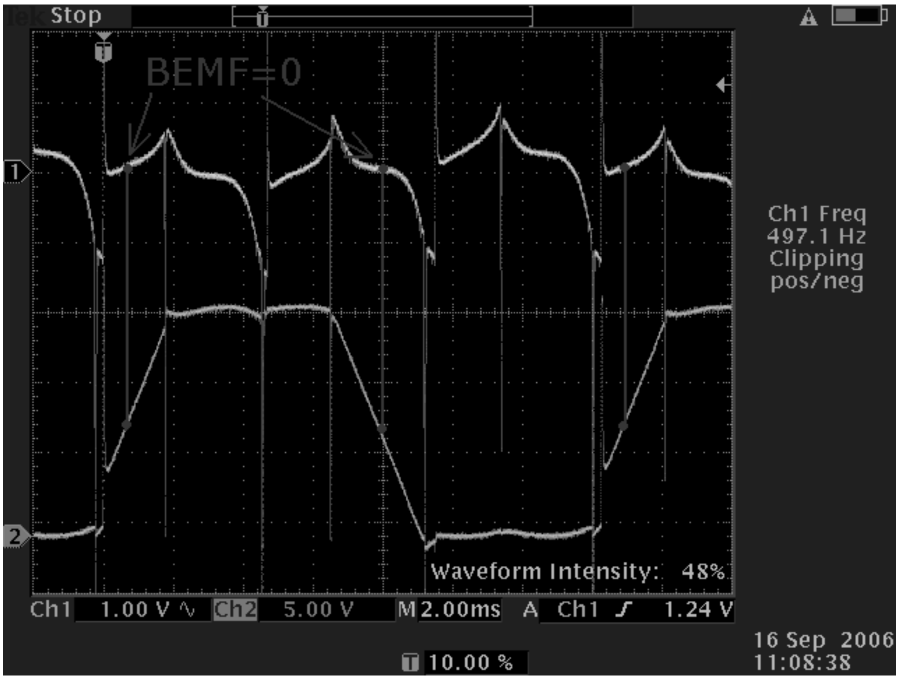


Fig. 3. Actual voltage waveform in the star point (yellow), actual voltage waveform of back EMF in one winding (blue) with marked zero crossing points

As it can be seen in Fig. 2, zero crossing points of back EMF voltages coincide with zero crossing point in the star point. Therefore one comparator is sufficient to determine the position of the rotor. Presented waveforms are measured for the case when the pump is supplied by full voltage – when the velocity is not controlled through PWM modulation. In case of velocity control, due to fast changing voltages the application of this method is difficult. Then it is better to measure the back EMF at the moment of turning off the PWM wave. Fig. 4 presents equivalent circuit of the motor at the moment of turning off PWM.

Fig. 4. Current flow in the circuit at the moment of turning off PWM

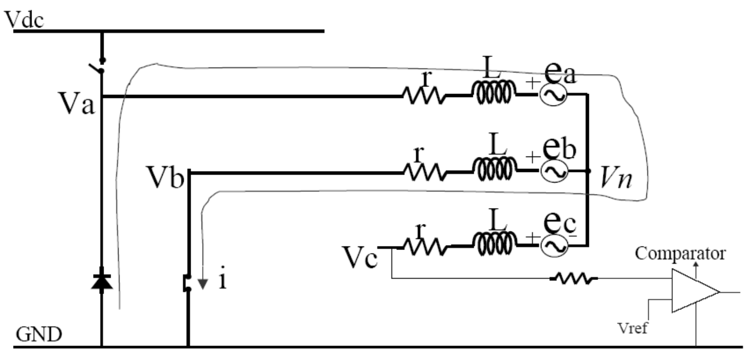


Fig. 4 presents the model of brushless motor at the moment, when current flows through A and B windings. Back EMF voltage is induced in not supplying C winding. We can easily notice from this figure that:

$$v_c = e_c + v_n \tag{1}$$

Where Vc is the C winding voltage, ec is back EMF voltage of C winding and Vn is the voltage in the star point.
If we omit diode's forward voltage, then for A winding it is possible to write:

$$v_n = 0 - ri - L\frac{di}{dt} - e_a \tag{2}$$

Similar equation will be for B winding:

$$v_n = ri + L\frac{di}{dt} - e_b \tag{3}$$

After adding these equations we obtain:

$$v_n = -\frac{e_a + e_b}{2} \tag{4}$$

Reassuming, in symmetric three-winding circuit at omitting third harmonic it is possible to present the equation:

$$e_a + e_b + e_c = 0 \tag{5}$$

After taking into account the third harmonic, we obtain the following equation:

$$e_a + e_b + e_c = e_3 \tag{6}$$

Further analysis is performed at omitting the third harmonic. From (4) and (5) we can write:

$$v_n = \frac{e_c}{2} \tag{7}$$

Therefore C winding voltage equals:

$$v_c = e_c + v_n = \frac{3}{2} e_c \quad (8)$$

At the moment of opening the upper switcher in PWM modulation, the voltage in the point C of the pump is proportional to the back EMF voltage of C winding. It can be noticed that during the measurement the voltage is noiseless. It results from turning off PWM, what implies the lack of supply. The second advantage is the symmetry of back EMF voltage. Thanks to it, there is no need to use the reference voltage to determine the zero point. These two advantages imply precision comparator's output signal, what in turn has the large influence on the quality of regulation process. If we take into account the third harmonic, we obtain from (4) and (6):

$$v_n = \frac{e_c}{2} - \frac{e_3}{2} \quad (9)$$

Hence it is possible to determine the voltage in the point C of the motor:

$$v_c = e_c + v_n = \frac{3}{2} e_c - \frac{e_3}{2} \quad (10)$$

Basing on the above formula, it is possible to notice that the third harmonic is apparent in the point C of the motor. However it will be coincident with basic wave and will not have the influence on zero crossing point. Fig. 5 presents the oscillogram of the voltage in one point of the motor. Here, we can notice

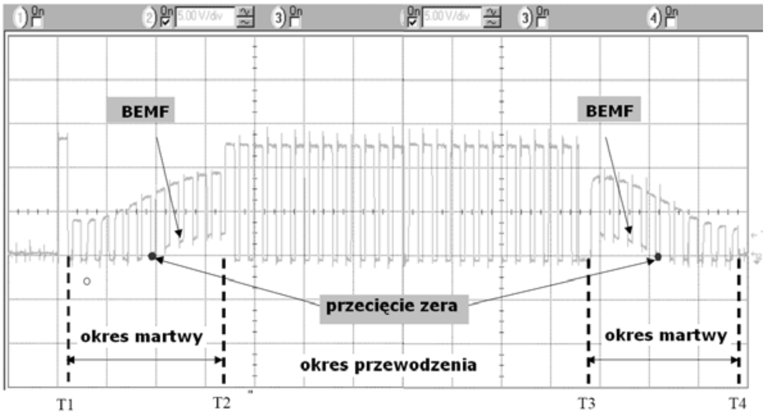
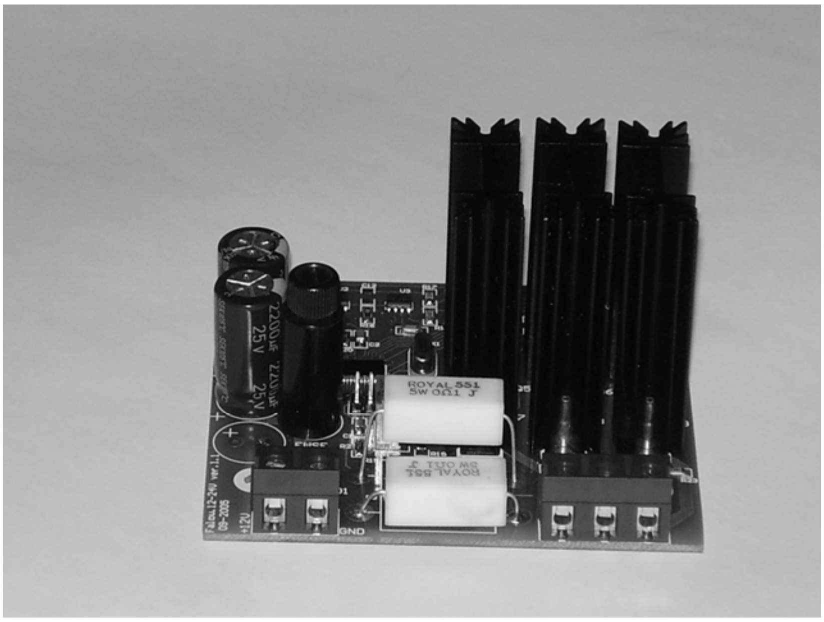


Fig. 5. Voltage oscillogram of the one point of the motor with marked zero crossing points

the idle time T1-T2 and T3-T4 corresponding to the situation when the current does not flow through the winding. Back EMF voltage induces during the idle time and sums up with the star voltage of the pulse shape. Due to zero crossing point occurs at the moment of turning off PWM only the low part of the oscillogram deserves our attention. Zero crossing points are marked with red dots.

Pict. 4 presents the view of the prototype device.



Pict. 4. Prototype device

4. INVESTIGATION OF THE PUMP

The investigation of the pump comprises the influence of the supplying voltage on the turning velocity, the influence of the supplying voltage on the quantity of pumped water, and the measurement of the power drawn from the circuit at the different turning velocities. In order to check the restarting procedure, the motor was stopped while supplying and its behavior was observed. The pump was fed by stabilized voltage source and worked in closed cycle – the operating conditions are very closed to conditions occurring in central heating system. The investigation results are presented in the following figures.

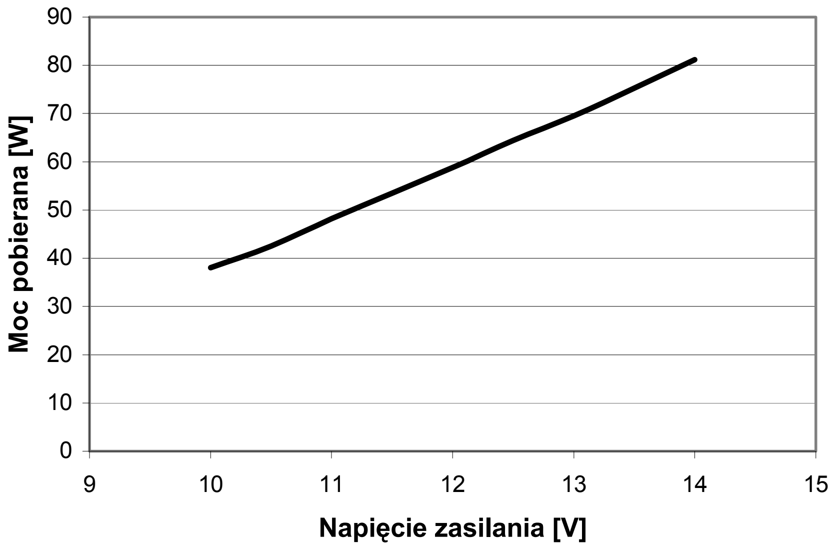


Fig. 6. The influence of the supplying voltage on the power drawn from the pump

Turning velocity of the pump has been determined on the basis of voltage oscillograms measured in motor's windings. Exemplary oscillogram is presented in Fig. 3.

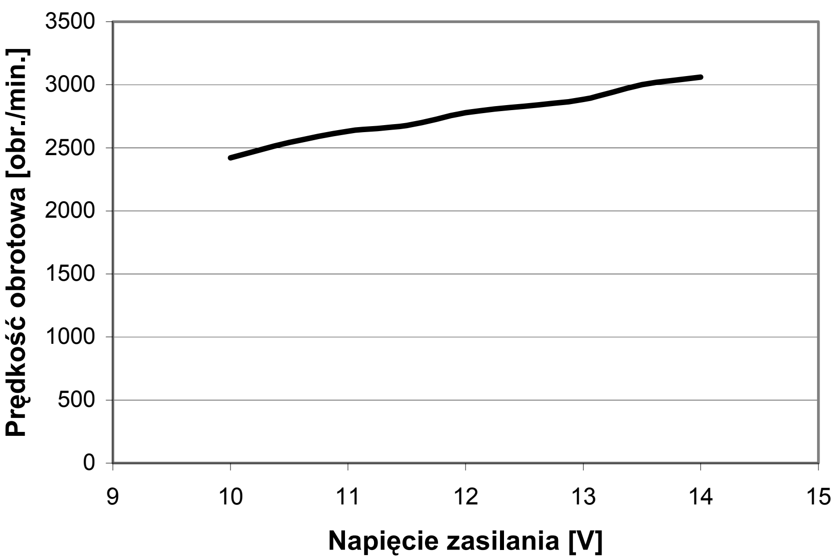


Fig. 7. The influence of supplying voltage on the turning velocity of the pump

Fig.3. Voltage oscillogram of two bands of the winding

The measurement of the pump efficiency has been carried out for 1 hour at supplying voltage equal to 10 V, 12 V and 14 V. The efficiencies of the pump were measured with the use of the water flow meter and were equal to 0,786 m3/h, 1,008 m^3/h and 1,152 m^3/h respectively. Additionally the efficiency of traditional pump fitted with asynchronous motor has also been measured. Its efficiency was equal to 1,015 m^3/h at the supplying voltage equal to 230 V. Therefore both solutions are comparable. The measurement of the power drawn by both pumps showed that the efficiency of our solution is 20% higher than the pump fitted with asynchronous motor. The test of restarting procedure suicides – pump's motor restarts every time.

5. CONCLUSION

Elimination of position sensors from pump's motor decreases the cost of the system and increases its reliability. Additional advantage is the elimination of the necessity of tuning of sensors. The largest advantage of presented solution is its continuous operation even at the breakdown of the power net. Owners of houses being placed in suburbs particularly appreciate this advantage. This pump consumes also much less energy than already existing pumps. Additional advantages are also continuous control of the turning velocity and its efficiency. The drawback of this solution is its higher price resulting from the cost of electronic device controlling the motor's operation.

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Manuscript submitted 09.02.2009
Reviewed by Jarosław Zadrożny

POMPA OBIEGOWA DO SŁONECZNYCH PANELI GRZEWCZYCH

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STRESZCZENIE *W pracy przedstawiono pompę małej mocy przeznaczoną do obiegu płynu w słonecznych panelach grzewczych. Do napędu tej pompy zastosowano bezszczotkowy silnik prądu stałego przy budowie którego wykorzystano elementy silnika indukcyjnego. W silniku tym nie ma typowych czujników położenia wirnika względem stojana. Położenie wirnika określane jest na podstawie przebiegu napięcia w sztucznie stworzonym punkcie zerowym. Pompa zasilana jest ze źródła o napięciu 12V i dzięki temu może być stosowana w warunkach awarii sieci energetycznej. Artykuł przedstawia konstrukcję silnika i konstrukcję układu elektronicznego oraz podstawowe charakterystyki i porównanie z dotychczas stosowaną pompą.*